

NIKE3D Enhancement and Support



For more information contact **Michael A. Puso**
(925) 422-8198, puso1@llnl.gov

LLNL's NIKE3D, an implicit structural-mechanics finite-element code, is a first-class simulation tool. The objective of our work is to enhance, maintain, and support NIKE3D.

Project Goals

We are adding features to NIKE3D to accommodate the evolving needs of LLNL's engineering efforts. Maintenance includes fixing bugs and porting code to the various platforms available to analysts. User support includes recommending approaches and assisting analysts in debugging specific models.

Relevance to LLNL Mission

One of the important functions of engineering analysts is to ensure structural performance and integrity as program designs evolve. Our suite of codes

has a record of contributing to these activities over many decades, through sustained, responsive support of project analysts. NIKE3D, in particular, is an excellent code for handling difficult non-linear static structural analysis problems.

FY2004 Accomplishments and Results

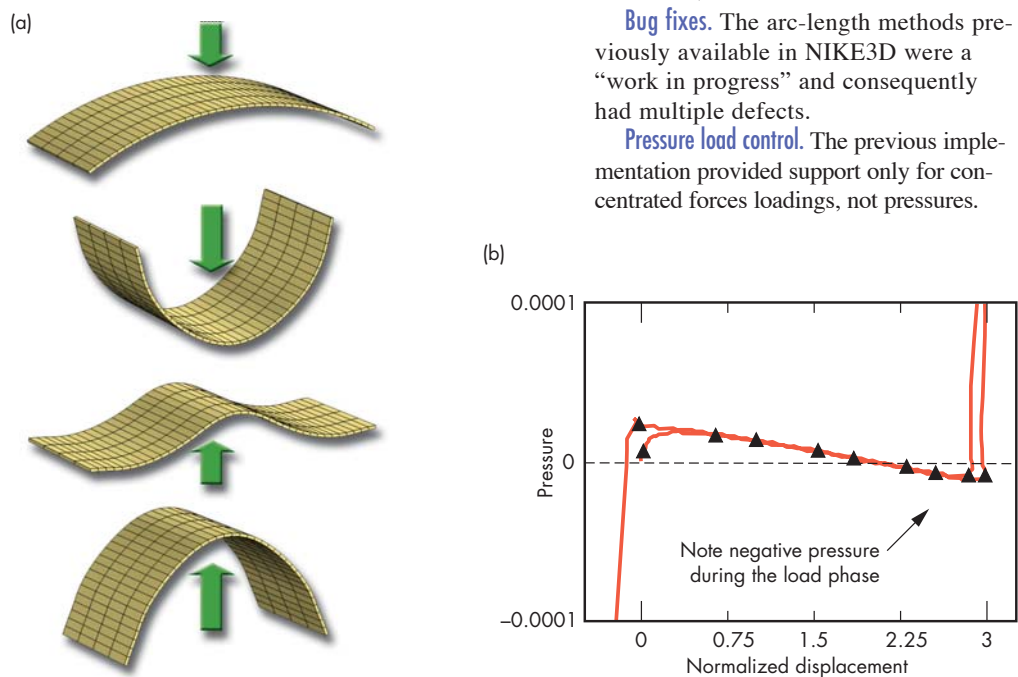
Continuation methods are nonlinear solution techniques used to solve analysis problems in the post-buckling regime of loading. The standard Newton-Raphson methods often fail in the post-buckling region when load control is applied. Continuation methods modulate the applied loading to meet some target metric of deformation (such as arc-length) or force residual (minimum residual method). These techniques allow solution into the post-buckling regime.

The following improvements were made to NIKE3D:

Bug fixes. The arc-length methods previously available in NIKE3D were a "work in progress" and consequently had multiple defects.

Pressure load control. The previous implementation provided support only for concentrated forces loadings, not pressures.

Figure 1. (a) Cyclic loading sequence for normal pressure on arched membrane. Pressure initially forces membrane downward to some given displacement and then reverses loading direction. (b) Pressure vs. normalized displacement for sequence in (a). The pressure loading begins positive but eventually becomes negative at "snap through." Pressure then becomes positive again as the membrane stiffens due to tension in the second of the four stages in (a). Pressure and sequence is then reversed.



The latter is an important feature necessary for many post-buckling problems of shells.

Cyclic loading. Standard continuation implementations always require the load steps to advance the deformation. A cyclic loading capability was implemented so that the deformation can be applied cyclically, as seen in Fig. 1.

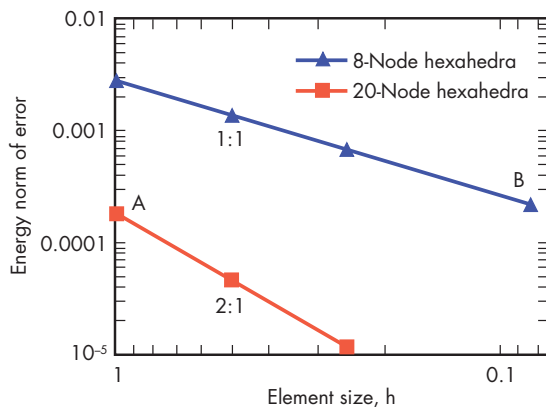
Minimum residual method. The minimum residual method was extended to work with our BFGS quasi-Newton nonlinear solver. The method often works better than the standard arc-length method.

A variety of additional continuum elements, using quadratic spatial discretization, were added to NIKE3D. These include 20- and 27-node hexahedra and 10-node tetrahedra. Available options

include assumed strain versions with linear pressure distributions. The discretization error, measured as the energy norm of the error, converges linearly for linear element types (8-node hex and 4-node tet) and quadratically for the quadratic elements (Fig. 2). These elements can drastically reduce the overall degrees of freedom (DOFs) required to attain a desired amount of accuracy. For example, from Fig. 2, considering the data in the table: Point A corresponds to using 192 20-node brick elements, while Point B corresponds to 41,472 8-node brick elements, yet the discretization error is nearly the same. The CPU time for the equivalent accuracy is 5500 times greater with the 8-node bricks.

FY2005 Proposed Work

Due to the varying demands of user support and user-requested feature addition, our typical planning strategy is to identify a set of logical "next steps" for feature deployment. For next year these include: the production version of mortar contact by generalizing algorithm data structures to make them compatible with the general features of NIKE3D; the implementation of a new anisotropic-damage material model for geological materials; and the incorporation of the capability to use a shared-memory parallel direct equation solver on Linux computers.



	Discretization error	Total DOFs in model	CPU time for sparse, direct factorization
Point A (20-node bricks)	1.87×10^{-4}	444	0.06 s
Point B (8-node bricks)	2.18×10^{-4}	131,400	330 s

Figure 2. Discretization error for pressurized thick sphere with quadratic 20-node and linear 8-node hexahedra, vs. element size.